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THEORETICAL AND PRACTICAL ISSUES REGARDING U.S. ARMY AMMUNITION FREIGHT MOVEMENTS

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ABSTRACT

This paper explores and discusses a variety of theoretical and practical issues related to the freight transportation industry in an attempt to relate relevant analysis techniques to United States Army shipments of ammunition. A number of topics are discussed, paying particular attention to mathematical freight models developed within the past two decades. Practical applications of modelling and analysis techniques are explored with respect to trip generation and trip distribution. These "applications of theory" are intended to (a) broaden the author's knowledge in the implementation of current methods and (b) aid in the determination of the usefulness of these methods as analysis tools for the United States Army.

The motivation for this paper is to determine if the U.S. Army can improve transportation operations through the use of improved planning and analysis tools. The specific question to be addressed is whether transportation system efficiency can be improved if transportation modelling practices are adopted.

As the objectives of this paper are geared toward expanding the author's knowledge as an analyst for the United States Army, it would be incomplete without at least a general overview of the military transportation system as well as the regulatory guidelines and special considerations related to

the transport of hazardous materials (HAZMAT). As such, an overview of U.S. Army transport relationships as well as a look into HAZMAT transport is included.

The author points out distinct possibilities for use of modelling techniques by the U.S. Army in planning for and managing shipments by commercial carrier.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

There can be no denying that we live in a changing global environment. Few professions in our society have recently felt, or will feel in the future, these changes like our nation's armed forces. Cold War victory will lead to many far-reaching changes in the Department of Defense (DOD). Just as European force reductions due to changes in the Warsaw Pact have led to reexamination of the nation's power projection requirements and alternatives, changing attitudes in the United States about the size of the defense force (and budget) must be addressed.

The most recent round of defense cuts, base closure hearings, and force reductions have forced the DOD to look at ways to do more with less. As the force becomes more and more a "home-based" one, the role of commercial transport will continue to be extremely important. The DOD cannot hope to simply ask carriers to charge less for their services because money is short. The DOD, specifically the Military Traffic Management Command (MTMC) must keep pace with the highly technical transportation industry to reduce costs and improve efficiency.

Objectives

Primary

The objective of this paper is to conduct a review of modelling and analysis techniques used to analyze freight movement to understand more fully the concepts at work in the industry. The intent is to provide a macro-systemic view of freight analysis assessed within the limited context of U.S. Army ammunition movement by commercial carrier. Limiting discussion to one general commodity will restrict the scope of discussion, while choosing the most "important" commodity, in terms of special considerations, will bring additional factors into the discussion.

Secondary

Where possible, the author applies techniques reviewed and discussed to further assess their usefulness for the military. Applications are an attempt to replicate model results utilizing a database of (a) ammunition shipments over the past year (Chapter 3) or (b) commodity and transport data from the 1977 Census (Chapter 2). These practical applications improved the author's skill and awareness with respect to freight analysis techniques.

Background

A basic introduction to the Department of Defense Transportation Component Commands and hazardous materials transport follows to assist the reader with the very limited scope of the freight industry under examination. In

addition, an overview of current analysis techniques and those utilized for this paper is also presented.

Overview Of U.S. Army Transportation Relationships

The United States Transportation Command (USTRANSCOM) is the single-manager in the Department of Defense (DOD) with overall responsibility for air, land, and sea transportation. USTRANSCOM is divided into three transportation component commands, or subcommands.

Air Mobility Command

The Air Mobility Command (AMC) is a U.S. Air Force agency responsible for all aspects of military airlift transportation, both in the continental United States (CONUS) and overseas (OCONUS).

Military Sealift Command

The Military Sealift Command (MSC) is a U.S. Navy agency responsible for sealift transportation, including augmentation by commercial shipping in time of war.

Military Traffic Management Command

The Military Traffic Management Command (MTMC) is a branch of the U.S. Army Transportation Corps responsible for traffic management, operation of common-user ocean terminals and transportation and transportability engineering. The MTMC advises the services and agencies how to select domestic freight carriers. It also negotiates freight rates in CONUS and routes truckload shipments requiring special services.

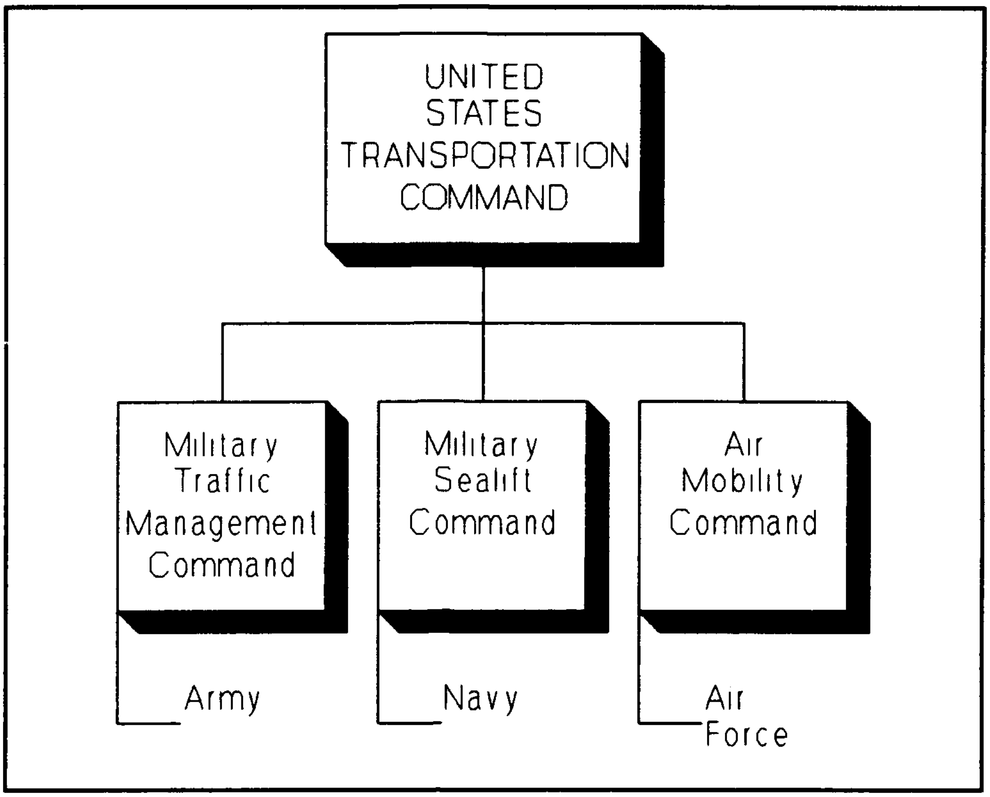

Figure 1
Transportation Component Commands

The Depot System

The U.S. Army Material Command (U.S AMC) is responsible for the operation of weapons and ammunition storage facilities in CONUS and OCONUS, as well as general supply depots.

These depots provide small reserves of ammunition (and other supplies) to be utilized regionally for scheduled active Army, reserve component, or National Guard training. Depots also hold large reserves in the event of war. This paper focuses on movements of controlled cargo (ammunition, explosives and weapons) between these depots as well as

movements from ammunition plants supplying the DOD.

Hazardous Materials Movement

While the DOD ships many commodities in the United States, this paper deals only with very specialized ammunition shipments which are subject to federal regulations controlling such movements on public highways. A detailed overview of the regulations and special considerations inherent with such shipments is provided in Appendix A - U.S. Army Safety and Security Requirements and Appendix B - HAZMAT Transport Regulations.

Analytic Tools Available

The research for this paper included a literature search and review of freight models, modelling techniques, optimization methods and other analyses related to freight transport. The search revealed extensive work covering many disciplines such as economics, geography, operations research and civil engineering. Included in this research was a trip to Joplin, Missouri, the headquarters of Tri-State Motor Transit -- the largest mover of munitions for the DOD. This brief visit and orientation served to demonstrate the highly technical nature of this portion of the industry, and highlighted the gap between the industry and the DOD in terms of modern analysis tools.

In this paper the following tools were utilized:

a) Regression techniques using LOTUS 1-2-3 and

SAS software packages.

b) Linear programming using the General Algebraic Modelling System (GAMS).

c) Modelling approaches as discussed in later chapters.

Organization

This paper is divided into five chapters. **Chapter 1** provides an overview of the concept of modelling and looks into freight equilibrium, shipper/carrier decision, and large scale macro models found in the literature. **Chapter 2** is an example of a freight generation sub-model and **Chapter 3** is an example of a freight distribution sub-model. **Chapter 4** addresses freight assignment from the carrier's point of view. **Chapter 5** assesses the concepts discussed in the previous chapters as they apply to U.S. Army ammunition movements and provides the summary and conclusions.

Chapter 1

TRANSPORTATION MODELS AND FREIGHT TRANSPORTATION

Models

A model is a simplified representation of reality containing the basic aspects of the phenomenon under scrutiny. Models are constructed and used as methodological tools in the planning process. Through their use, important inter-relationships among variables become more apparent, providing insights for possible improvements. As a model becomes more sophisticated, additional details are included to more meaningfully represent a real-life situation. The more realistic the model, the more desirable it is; however, the level of sophistication may be constrained by insufficient data, funds, time and knowledge about the real world.

Transportation Model Systems

A transportation model system is best defined by interpreting the component parts of the term: **Transportation** - "the process of safely and efficiently moving people and goods from one place to another"; **Model** - "a representation of reality"; and **System** - "an orderly set of inter-related parts." The development and implementation of such a model system can assist transportation planners and decision makers. A transportation model can take on many forms, shaped by different ideologies, needs and constraints.

Freight Models

Models that seek to analyze only commodity movements are referred to herein as freight models. Such models represent only a fraction of the transportation modelling field. Much more time and effort has gone into modelling passenger flows and the effects upon urban planning and congestion. There are several types of models available for freight forecasting: equilibrium models, shipper/carrier decision (or mode-choice models) and Urban Transportation Planning System, or UTPS-type, macro models. These classes are not entirely exclusive. Equilibrium and/or mode choice models may form a component for a macro model (Goulias and Pendyala, 1990, p.1).

Freight Equilibrium Models

"It can be assumed that some sort of economic optimization process underlies commodity transport decisions" (Kanafani, 1983, p. 279). Freight transportation models, which embrace the concept of economic supply-demand equilibrium, are worth observing from both the shipper and carrier perspective. Such models can either be termed as Econometric, Spatial Price Equilibrium (SPE) or Freight Network Equilibrium (FNE) (Harker, 1987, p. 25).

Econometric Models

Econometric modelling can basically be placed into one of three categories:

a. Supply-Side Models

b. Demand-Side Models

c. Integrated (Supply-Demand) Models

Supply-side models are concerned with the production/cost characteristics of the freight transportation industry. Examples of such work include Friedlaender (1978) and Chow (1978) who each reported diseconomies of scale in the longhaul less than truckload (LTL) and truckload (TL) industries. Such works have been used to discredit any claims of economies of scale in the motor carrier industry.

Demand-side models are concerned with explaining the demand for freight services based on the rate charged for these services combined with associated levels of service (LOS).

Integrated models, which look at both supply and demand, seek to provide an equilibrium prediction and are intended to answer policy issues with broad impacts, such as deregulation. Supply and demand equilibrium is a condition that exists due to "market forces" in a competitive economy. Suppliers will produce goods or services at a level that maximizes marginal profit, likewise, consumers will demand goods or services at a level commensurate with marginal utility. The result is a level, at equilibrium price, that satisfies both consumers and producers. If a producer requires a higher price than consumers are willing to pay, the market will drive the price down. Such an economy must

be devoid of trade barriers, consumers should have a choice of producers, information about prices must be free flowing, and the market is assumed to be very responsive with respect to time.

In 1976 Friedlaender proposed a four component system for freight demand forecasting. The four interactive components of the model were:

a. A Regional Transportation Model

b. A National Input-Output Model

c. A National Macro Model

d. A Regional Income Model

While the model was formulated at an aggregate level for ease of use, the study involves no data analysis or statistical estimation (Friedlander 1976).

Network Equilibrium Models

Network (SPE and FNE) models differ from the econometric models in that the transportation system is explicitly represented by a network. Econometric models do not consider the transportation system in such detail , choosing only to consider "very simple descriptions of the network" (Harker, 1987, p. 9).

The network models describe the transportation system as a set of nodes and arcs. Associated costs and LOS measurements are included in most network representations, and as such network models do not lend themselves to long-run analysis. Such analysis would require the network

representation to fluctuate to represent changes due to capital improvements on the transportation infrastructure.

Spatial price equilibrium models utilize demand functions associated with consuming regions and supply functions with producing regions. The shippers then reach equilibrium between regions when the following conditions are realized:

a) If there is flow of commodity i from region A to region B, then the price in A for commodity i plus the transportation cost from A to B will be equal to the price of i in B.

b) If the price of commodity i in A plus the transportation costs from A to B is greater than the price of i in B, then there will be no flow from A to B. In such a way then, the demands for transportation are derived from market forces across regions.

Freight Network Equilibrium Models focus on the actions of carriers, shippers and potential shippers on the network. Friesz, et al. (1981) developed a model for the U.S. Department of Energy in which shippers act on a perceived network, which is an aggregate of the physical network on which the carriers act. Demand behavior was initially looked at as a fixed set of origin-destination (O-D) pairs. Once the equilibrium for the perceived network is found, the flows are disaggregated to form carrier-specific relationships.

Harker (1987) took a step forward with the Generalized Spatial Price Equilibrium Model (GSPEM) that attempted to bring all three network equilibrium models together as one. The model incorporates behavioral models of producers, consumers, shippers, and carriers. Each model is a subset of the GSPEM. The major assumptions of the model are:

a) Carriers individually minimize the cost of transporting goods over their networks.

b) Carriers price according to demand.

c) Supply equals demand in each transportation market.

d) Shippers individually minimize the cost of shipping goods over their network.

e) Shippers send goods between regions only if it is economically attractive to do so.

f) There is conservation of freight flows in every region.

Under these conditions, finding an equilibrium freight flow involves the solving of a constrained optimization problem where the costs of shippers and carriers are optimized (a typical operations research problem).

Freight Mode Choice Models

Models attempting to reflect the freight demand for a given mode choice basically fall into two categories. Aggregate models deal with a portion or all of a particular industry attempting to capture the percentage of market

share demand for mode i. The disaggregate approach deals more with individual decisions for particular shippers choosing between modes.

The aggregate model in its basic form is represented by (Oum, 1980, p. 12):

$$\log S_i/S_j = a_o + a_i\,(P_i - P_j) + \sum ak(X_{ik} - X_{jk})$$

where:

S_i/S_j represents the market share of mode i as compared to mode j
P_i-P_j represents the price differential between modes
$X_{ik}-X_{jk}$ represents a difference in other variables

In the model a higher percentage of market share is attributed to the mode that can (a) offer the most economical choice and (b) react best to "other" market needs such as delivery time, reliability, security, etc.

Disaggregate analysis "is motivated by the proposition that each manager is concerned with maximizing utility" with respect to expense and service from a given mode for each shipment (Winston, 1983, p. 422). A random expected utility (see Chapter 4 for a discussion of utility) model of the following form is used to represent the motivating factors for mode choice mode:

$$EU_i(Z_{iS}) = V(\beta;\bar{z}_i,S) + \eta(Z_i,S)$$

where:

EU_i = The expected utility for mode i
V = The mean or representative utility
β = Vector of unknown parameters
Z_i = Vector of actual or mean values of the

attributes of the ith mode, commodity and firm
S = Vector of commodity and firm characteristics
η = Unobserved characteristics

The freight manager will select mode i if $EU_i > EU_j$ for all j not equal to j.

Winston developed a fully disaggregate model of shipper and receiver mode choice and later utilized the results to study the effects of deregulation on surface freight. This disaggregate study of shippers' and receivers' decision making processes provided insight to the study of the time period from 1929 to 1988 where modal shares for rail fell from 75 percent to 37 percent, while truck shares rose from 3 percent to 25 percent (Winston, 1990, p. 2).

In Winston's mode choice model the probability of choosing freight mode i is a function of:

a) Freight Charges

b) Average Transit Time

c) Standard Deviation of Average Transit Time

d) Coefficient of Variation of Transit Time

e) Shipment Size

f) Value of Commodity Shipped

g) Distance of Shipping Firm from a Rail Siding

h) Sales of Shipping Firm

The model was estimated from a sample of shipments in 1977 that included all major commodity groups except coal and grain (Winston 1990, pp. 16-17). Mode choice was determined between three choices: rail, motor common carrier, and

private truck.

The Formal Model (a trinomial probit model) presents the probability of choosing mode i as a function of multivariate normal frequency function. The mean expected utility of a mode is expressed as a linear parametric function of the explanatory variables (Winston 1990, p.18). The study concluded that freight charges were the most significant factor for all commodities with respect to mode choice. Winston and Wilson (1980) each explored factors affecting the rate function (factors that describe the price charged for services), a major impact upon mode choice. Each found that transit time was highly variable with respect to elasticity of demand (Wilson, 1980, p. 11). This variation could be linked to the type of commodity being shipped. Shippers of produce are much more concerned with transit time than shippers of coal or fabricated metals.

In 1974 Hartwig and Linton conducted a similar study using freight bills containing information on origin-destination, freight charge, shipment weight, routing, type and number of commodities, date shipped, and date received. Discrete choice models including logit, probit, and discriminant analysis were utilized. The study concluded that freight cost, reliability, and commodity value were the most significant factors affecting mode choice (Hartwig and Linton, 1974).

By developing what he termed as the Transportation

Sectoral Unit Cost Function, Oum (1980) utilized neoclassical economic theory (minimization of a cost function given a performance function representing the production technology available to the shipper) to determine modal revenue shares. The data for his analysis included:

a) Yearly traffic volume (tons/mode) for each commodity group

b) Average freight rate/ton

c) Average transit time and variability by mode

d) Link distances between origins and destinations

Both Oum and Vinod (1970) give considerable thought to using the same unit cost function for all shippers of the same commodity for ease of computation. The premise, similar to Winston's findings, is that shippers will seek to minimize the cost function available to them, given a required level of service. Oum developed four interacting models: a general model, a model strictly independent of distance, a model with mode-specific aggregators and a fully aggregated model. Each of the models is presented evaluating speed and reliability (measured by on-time performance statistics), speed alone, and reliability alone.

UTPS Macro-Models

Freight modelling is still in its infancy in terms of development if compared to passenger modelling systems. It is not surprising, then, that many of the large scale

freight transport demand forecasting models are fashioned after the "Classic Transport Model" (Ortuzar and Willumsen, 1990, p. 22). The model, also referred to as UTPS (fig. 2) is an iterative approach that lends itself to continuous transport planning and decision making. There are four basic sub-models in the system: trip generation, distribution, modal split, and assignment.

The early work of Vinod (1969) is an example of the classic model used to study freight transport demand. His model is organized roughly in the same manner as discussed above, neglecting only the assignment sub-model. The variables used in the model system include shipment weight, value of shipment, tariff rate, shipment distance, employment rate, per capita income, and retail sales.

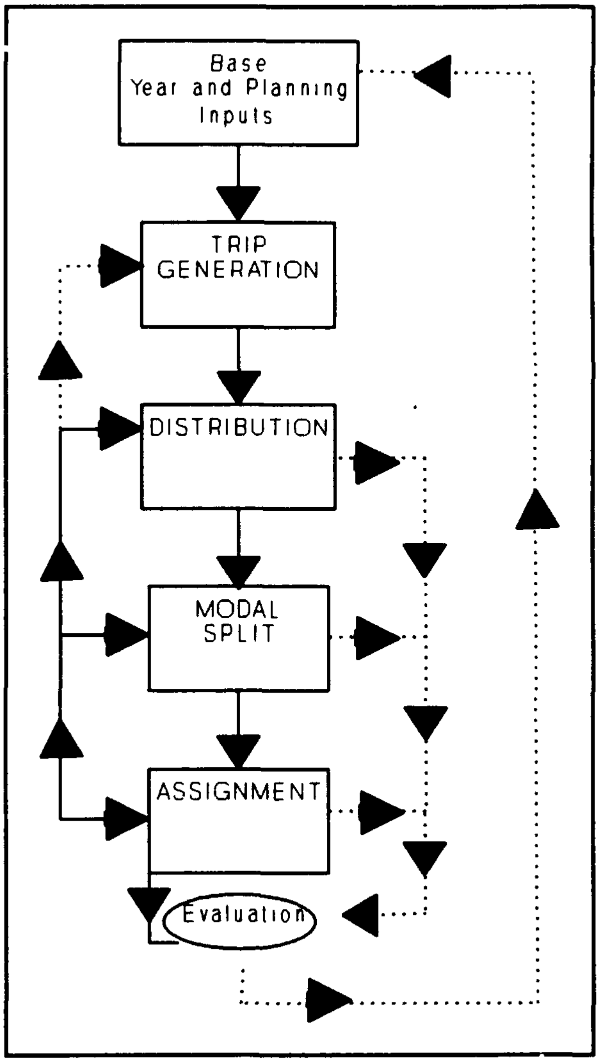

Figure 2 - UTPS Model. Source: Ortuzar and Willumsen, 1990, p. 23.

Chisholm and O'Sullivan (1973), while entertaining a variety of methods, followed

the same process in their spatial analysis of the British economy, as did Southworth, et al (1982) as part of the Chicago Area Transportation Study (CATS). Southworth's model consists of total truck generation, distribution, and assignment models.

The basic "sub-models" have distinct outputs, but operate iteratively as well. The sub-models are discussed in turn below.

Trip Generation

A basic step in the analysis of freight flows is the development of some type of relationship by which one can estimate freight volume generated and attracted by locations.

> "Once a relationship between freight volume and one or more independent variables has been established, it becomes possible to predict the effects of changes in the independent variables upon the pattern of goods traffic" (Chisolm and O'Sullivan, 1973, p. 36).

Studies by Southworth. et al. (1982) and Kim-Hinkle (1982) utilize linear regression to link the dependent variable (trips generated or attracted) to one or more independent variables. The intent is to use regression as a tool for uncovering causal relationships affecting freight movement. In the absence of this technique, many regional planners have expressed freight movements as "a percentage of passenger movements" (Stopher and Meyburg, 1975, p. 122). Such attempts are not normally successful. While the volume

of freight movements can generally be described as less than that of passenger movements for most areas, there is no causal relationship between the two in most cases.

A successful representation of freight flows was developed by Ogunsanya in 1984. He formulated a curvilinear regression model for freight generation in Kenya. The model was represented by (Ogunsanya, 1984, p. 183):

$$\log y = b_0 + b_1 \log x_1 + b_2 \log x_2 \ldots b_7 \log x_7 + e$$

where:

Y = Freight Generation in Tons
X_1 = Population in Millions
X_2 = Land Use (a dummy variable describing residential, commercial, industrial...)
X_3 = Import Freight Volume in Tons
X_4 = Intra Freight Volume in Tons
X_5 = Zonal Freight Demand in Tons
X_6 = Export Volume in Tons
X_7 = Zone Size in Square Miles

The author reports a 99.74 percent explanation of "total variation in freight generation" over a two year period in Kenya (Ogunsanya, 1984, p. 181). Factors for other generation models include floor space, employment, commodity-specific relationships, distance from population centers, etc.

Chisholm and O'Sullivan estimated generations of freight over 78 zones in Great Britain using linear regression. Three independent variables were analyzed: resident population, employed population, and retail turnover (Chisholm and O'Sullivan, 1973, p. 40).

Distribution

Given the outputs from the first sub-model (generations and attractions) the distribution sub-model seeks to (a) determine the allocation of zone or node generations to specific destinations and (b) determine the allocation of attractions to specific origin zones or nodes. Output is total tonnage shipped between specific zones or nodes.

Chisholm and O'Sullivan utilized a gravity model approach for distribution; while Southworth modelled distribution as a factor of travel time (Goulias and Pendyala, 1990, p.9).

Modal Split

As discussed earlier in this chapter, this sub-model allocates origin-destination (O-D) flow to specific modes. Output is total traffic by mode between O-D pairs.

Assignment

This sub-model allocates O-D flows by mode to specific routes on the network. Output is tonnage carried by mode for each O-D pair by specific links available to each mode. This sub-model usually depends upon operations research concepts. Normal approaches include linear (Chisholm and O'Sullivan) and non-linear (Southworth) optimization techniques using Wardrop's First Principle of systems optimization where:

> "...agents involved in each O-D move compete non-cooperatively for the transportation resources such that they minimize their own costs" (Harker, 1987, p. 20).

Summary

The models discussed represent the "reality" of commodity transport from many different and many similar viewpoints. Analyses to this point, with few exceptions, have been extensions of passenger modelling. As the unique qualities of freight transport are integrated into models, they will improve just as passenger models have progressed.

Such motor carrier issues as "safety and highway investment" will play a major role in future representations of the network (Winston, 1983, p. 59). Decision models that work for passenger analysis may not always apply for freight. One example is the concept of "backhauling" -- what the truck does after delivery of its load (e.g., return to origin or move to next assignment). Most models treat backhauling the same as the original shipment, figuring that trucks trace their route back to their origin, whether loaded or empty ("deadhead"). "This is acceptable for shipper-owned transport, but not in the general case" (Friesz, 1983, p. 412).

As these and other industry-related issues, as well as economic and social factors, are brought to bear, freight models will become progressively better and their use will grow.

Chapter 2

A FREIGHT GENERATION MODEL

The original intent in this chapter was to create a trip generation model for DOD ammunition traffic and then apply it in the next chapter (Trip Distribution); however, demographic and or descriptive data regarding depot ammunition operations is classified "For Official Use Only" (FOUO) by the U.S Army and unavailable as a source for this paper. Some of the data requested from AMC that fall into this category include:

a) Number of employees

b) Number of transportation managers employed

c) Commodities stored at the depot

d) Tonnages stored for wartime stocks

e) Rotation period for commodities stored

f) Distance from railhead

In an attempt to circumvent this problem, other possible independent variables that may be statistically correlated were sought. Possibilities included: state-by-state active duty military strengths; proximity of largest military population centers to trip producing depots and industry statistics (from the 1987 Census of Manufactures) for ammunition, small arms and explosives producers by state. None of these data sets produced a statistically significant relationship to trip production/attraction with

either linear or curvilinear regression methods. This is not surprising for two reasons. First, the largest military bases do not necessarily use the most ammunition. Over 34,000 personnel are stationed in the Military District of Washington; however, very few fire a single round during the course of the year. Second, government shipments are not likely to be tied to commercial shipments except for deliveries from manufacturers, which account for only a small portion of the data accumulated. Another solution could be to relate level of conflict and location (during the Gulf War, nearly all shipments were directed toward ports on the east coast). This paper, however, deals only with normal, peacetime movements.

As a substitute for a generation model for DOD ammunition shipments, similar data were sought to carry out the intended process and demonstrate the techniques discussed in Chapter 1 regarding generation. The 1977 Census of Transportation, Commodity Transportation Survey, provides information by commodity on tonnages shipped from origins to destinations for selected geographical areas. (Note: The 1977 Census was chosen because it is the last census that provides a commodity transport summary. Later versions provide only Truck Inventory and Usage Statistics.)

Zonal Estimates

Trip generation models are nearly always aggregated to

some extent. This is generally accomplished by creating analysis zones. The size of these (and hence the level of aggregation) is determined by the level of detail desired by the study. This level of detail is further defined by the amount of time, energy, and resources available for the study.

1977 Census of Transportation

The data found in the census aggregate the Continental United States (CONUS) into nine zones and one category for unknown destinations. The zones (and representative states) are:

a) Northeast (Massachusetts, Rhode Island, Connecticut)

b) Middle Atlantic (New York, New Jersey, Pennsylvania)

c) East North Central (Ohio, Indiana, Illinois, Michigan, Wisconsin)

d) West North Central (Minnesota, Iowa, Missouri, Nebraska, Kansas)

e) South Atlantic (Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida)

f) East South Central (Kentucky, Tennessee, Alabama, Mississippi)

g) West South Central (Arkansas, Louisiana, Texas, Oklahoma)

h) Mountain (Colorado, Arizona, Utah)

i) Pacific (Washington, Oregon, California)

The data are summarized in Table I. The quantities represent thousands of tons shipped from zone to zone for commodity 344, with total tons shipped to and from each zone.

Table I - Tonnage (x1000) Shipped From Zone-to-Zone, Commodity 344. Source: 1977 Census of Transportation. (* - Includes unknown destinations)

From Zone:	NE	MA	ENC	WNC	SA	ESC	WSC	MT	PA	Total*
			To Zone:							
NE	277	36	19	15	29	1	9	1	4	402
MA	184	1218	681	133	626	187	133	57	39	3283
ENC	178	295	2929	614	375	247	235	81	109	5109
WNC	2	43	195	1516	70	47	103	32	43	2294
SA	80	130	141	22	2143	244	63	20	20	2957
ESC	16	29	132	285	356	569	273	35	8	1713
WSC	1	26	98	51	104	66	2526	84	55	3055
MT	0	2	12	3	32	0	20	81	164	314
PA	5	11	18	3	14	8	16	408	1224	1747
Total	743	1790	4225	2642	3749	1369	3378	799	1666	

Independent Variables

The independent variables come from the 1977 Census of Manufacturing, where industry statistics by geographic area are listed for each commodity grouping. An initial choice of Industry 3482 "Small Arms Ammunition" was ruled out due to incomplete data and replaced with Industry 344

"Fabricated Structural Metal Products." While this is certainly not hazardous or controlled cargo, it may resemble ammunition as a commodity in that it is not subject to spoilage considerations that may affect the decision to transport over long distances (e.g. fresh produce). Table II summarizes the data from the Census of Manufactures. This model will attempt to use two basic indicators for the industry as predictors for tonnage generated by zone: employment and production.

Table II - Tonnage Indicators, Commodity 344. Source: 1977 Census of Manufactures.

ZONE	TOTAL TONS	EMP (x1000)	PHR (milhrs)	VA (mil$)
NE	402	2.6	3.9	62.4
MT	314	3.1	4.6	69.1
ESC	1713	7.7	11.9	197.0
WNC	2294	8.1	11.5	222.0
PA	1747	9.3	13.0	291.0
SA	2957	13.0	18.5	298.0
MA	3283	14.9	20.1	389.0
WSC	3055	17.8	28.4	445.0
ENC	5109	16.5	23.0	456.0

Employment

A measure of the size of the individual firms, which, when aggregated, give an indication of the size of the industry in each zone, should be observed by employment statistics. Employment is represented in thousands of employees and designated by the variable EMP.

Production

Two possible measures of production are taken from the

Census of Manufactures. Production hours (PHR) measured in millions of man-hours and value-added (VA) measured in millions of dollars are used to reflect the impact of production on freight generation. Value added is a dollar figure used in the census to capture the price increase added to raw materials and before market products by the production process.

Model Derivation

As seen in the literature, deriving the freight generation model almost always involves some form of regression technique to form the basic model. Remembering that generation is only a sub-model of the macro-model, and that it will evolve with each iteration, it is not unrealistic to believe that a model such as this would begin with as few as one or two independent variables.

Investigating first a simple linear least squares regression with each of the three predictor variables separately and total zone production (TONS) yields the results in Table III. All three variables display a fairly high degree of correlation to tonnage generation. In fact any of the three could probably be used in this linear form as an initial model. Of course there is no guarantee that such a model would hold up to reevaluation in the iterative process. It is therefore imperative to attempt to develop the "best" model possible.

Table III - Freight Generation Model Results for TONS.

Variable	Intercept	Coefficient	T-Stat	R^2
EMP	-207.883	244.569	5.61	.818
PHR	- 32.308	156.892	4.41	.735
VA	-218.454	9.402	6.08	.841

Utilizing a stepwise regression analysis and transformation of the variables, Model 1, which utilizes VA as the sole predictor, is represented by:

$$ln\text{TONS} = (.747 + 1.24\ ln\text{VA}) \quad or \quad \text{TONS} = e^{(.747\ +\ 1.24\ ln\text{VA})}$$

With the following regression statistics : $R^2 = .940$; degrees of freedom = 7 and t-statistic = 10.448. Figure 3 shows a plot of TONS vs. VA and the fitted model.

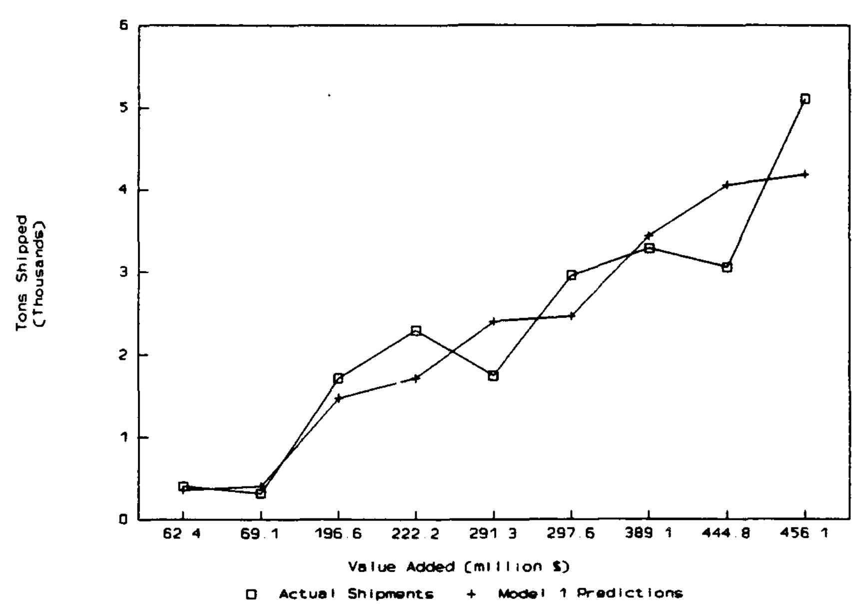

Figure 3 - Plot of Actual Data vs. Model 1 Results.

To achieve a better "fit" a dummy variable, D_1, was used to

differentiate shipments originating in Northern (D_1 = 1) and Southern (D_1 = 0) states. A similar indicator variable could be used addressing different ammunition commodity types stored at different depots. The final model, Model 2, takes the form:

$$\mathbf{TONS} = e^{(.441 + 1.279\, ln\, VA + .309\, D1)}$$

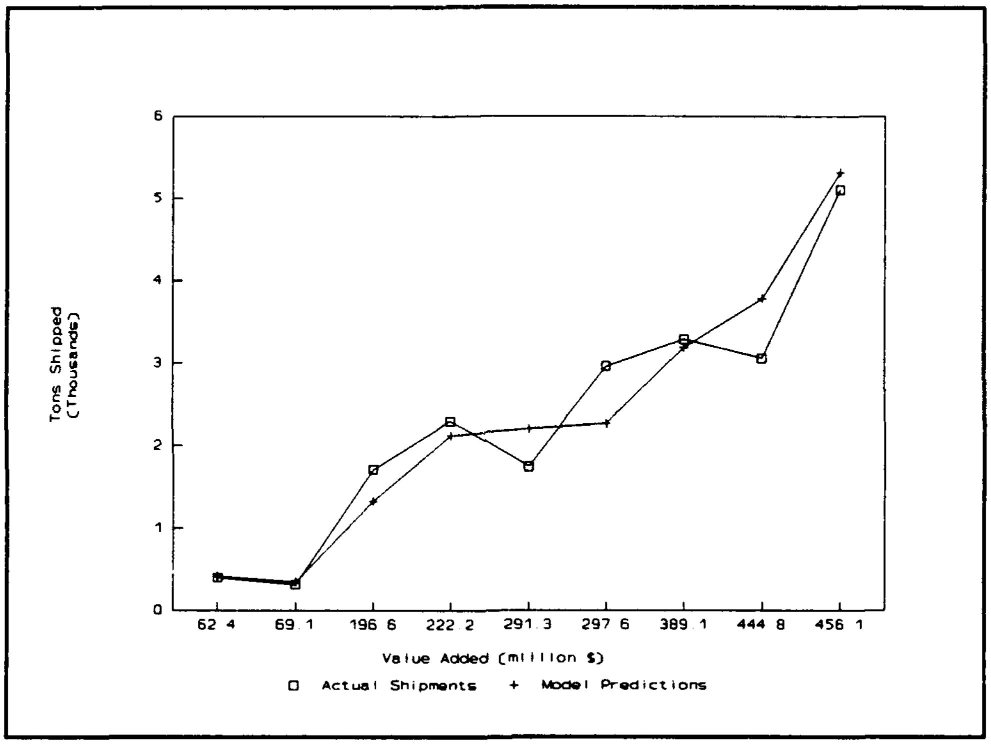

Figure 4 - Model 2 Plot vs. Actual Data.

With the following regression statistics : R^2 = .965; degrees of freedom = 7; t-statistic (VA) = 12.86 and t-statistic (D_1) = 2.08. Figure 4 depicts the final model vs. actual data. This output would then be used to feed the freight distribution sub-model.

Freight Attractions

While there is no practical application in this

chapter, the attraction sub-model is derived similarly. The choice of independent variables would be motivated not by measures of production, but attraction. Data of this type can be slightly harder to come by, and it may be useful to establish "baseline" levels with which to compare estimates. The key lies with discovering and expanding upon a relationship or suspected relationship that results in commodity or freight attraction. With respect to ammunition shipments one approach would be:

a) Determine the types of ammunition normally stored in each depot in the zone of analysis.

b) Determine normal usage patterns of Army units with respect to types of ammunition.

c) Determine location of units and proximity of depots. This likely relationship can be simplified by the analogy: tanks fire tank rounds and machine guns fire machine gun rounds, and is as elementary as knowing that most shipments of window air conditioners will terminate in hotter, more humid states.

Summary

The freight generation sub-model is an integral part of the UTPS model that uses varying degrees of basic mathematical concepts. While not difficult, development of the model must be careful, and utilization guarded.

Development

At the heart of developing such a model is (a) an

understanding of the relationship that is to be represented and (b) possession of good data with which to work. Lack of one or the other may not prove fatal; however, good data without an understanding of the concepts at work can lead to improper conclusions, and vice-versa.

Utilization

The most important concept when using such a model (especially one as simple as that developed in this chapter) is to understand possible sources of error. A basic understanding of regression dictates that the fitted model is just that -- fitted to the data. The analyst must recognize that either the data, regression or both can lead to very misleading results. Sound, well researched theoretical considerations will however provide a basis for assessment and evaluation of the results. For example, the excellent goodness-of-fit (R^2) of the two generation models presented earlier is due largely to the small sample size.

Chapter 3

A FREIGHT DISTRIBUTION MODEL

This chapter illustrates the use of the gravity model to determine freight distribution utilizing U.S. Army ammunition shipment data.

Gravity Model

This sub-model takes the output from the generation sub-model (total productions and attractions by zone), distributing the productions to specific destination zones, and the attractions to specific origin zones. Figure 5 illustrates the input and output of the process for a hypothetical 3-zone system.

To accomplish this task the gravity model, adapted from Newton's Law of Universal Gravitation (1686), utilizes distance or friction factors (F_{ij}) and specific zone-zone adjustment factors (K_{ij}). In most applications the model takes the form (Dickey, 1983, p. 203):

$$T^k_{ij} = O_i \frac{D_j F_{ij} K_{ij}}{\sum_{j=1}^{n} D_j F_{ij} K_{ij}}$$

where:

T^k_{ij} = Tonnage of commodity k shipped from i to j
O_i = Tonnage originating in i
D_j = Tonnage terminating in j
F_{ij} = Distance Factor
K_{ij} = Zone-to-zone adjustment factor

	Zone 1	Zone 2	Zone 3
Productions	6	5	4
Attractions	5	4	7

Generation Model Output

(Distribution Model Input)

		To Zone 1	Zone 2	Zone 3	Total Productions
Movement From Zone #	1	1	2	3	6
	2	2	1	2	5
	3	2	1	2	4
Total Attractions		5	4	7	

Distribution Model Output

Figure 5 - Illustration of Output of Distribution Model.

The Friction Factor

The friction factor in the gravity model has been the object of much discussion in the literature. Most sources endorse the form: $F_{ij} = 1/t_{ij}{}^{b}$ where t is a measure of distance or travel time and b is a derived exponent (usually .02 to 2.0) (Black, 1972). The purpose of the friction factor is to report a drop in F as the distance or travel time increases. The selection of the coefficient for this continuous form of the friction function may depend upon the commodity modelled. For instance, perishable produce would be far more susceptible to travel time than say, sheet metal.

Another method for depicting the friction factor involves a discontinuous function that separates the data into time intervals and assigns different factors to each. This method is used in the demonstration below.

Data

This chapter utilizes a database of U.S. Army ammunition shipments taken from the past 18 months (See

Appendix D). The database depicts origins and destinations of truck ammunition shipments. For this example the data are aggregated into six zones:

a) Northeast

b) Southwest

c) South

d) Midwest

e) West

f) Northwest

The high level of aggregation is intended to make the example more manageable. The calculations involved here,

Table IV - U.S. Army Ammunition Movement Trip Matrix and Average Trip Miles.

Zone Trips From:	To: 1	2	3	4	5	6	Total Prod:
Northeast (Zone 1)	1	16	1	10	17	5	50
Southeast (Zone 2)	8	27	71	86	113	17	322
South (Zone 3)	55	276	160	140	343	335	1309
Midwest (Zone 4)	16	66	32	84	159	31	388
West (Zone 5)	1	28	45	52	140	25	291
Northwest (Zone 6)	1	8	8	3	41	27	88
Total Attractions:	82	421	317	375	813	440	2448

Average Movement Mileage From:	To: 1	2	3	4	5	6
Northeast (Zone 1)	225	573	1467	571	2582	2057
	(117)	(271)	(174)	(162)	(203)	(664)
Southeast (Zone 2)	413	378	912	729	2605	2378
	(118)	(253)	(304)	(216)	(512)	(438)
South (Zone 3)	1388	885	427	822	1595	1112
	(228)	(265)	(227)	(232)	(269)	(677)
Midwest (Zone 4)	742	722	857	201	2120	1532
	(135)	(114)	(210)	(127)	(215)	(795)
West (Zone 5)	2761	2707	1678	2228	285	720
	(115)	(260)	(282)	(192)	(264)	(203)
Northwest (Zone 6)	2225	2272	1610	1575	640	512
	(371)	(412)	(675)	(490)	(215)	(495)

( ) = Standard Deviation

while simple, are numerous. Table IV summarizes actual zone trips and average distances for those trips. High standard deviations in average distance calculations reflect a need for less aggregation in the problem and will be a source of error. Again, this is the paradox of aggregation -- the trade-off between manageability accuracy. Trips, instead of tonnages, are used in this example. This is an acceptable substitute given the non-compatible nature of ammunition that makes nearly any tonnage shipment a truckload movement. One vehicle movement then, equals a trip.

Calibration

The role of calibration is to derive the friction factors for the basic equation. This is achieved in a two step process. Step one uses the basic equation to attempt to match origination totals for each zone. Friction factors are adjusted after each iteration based upon the results as compared to actual originations. This iterative process continues until an acceptable tolerance is achieved. During this process the total attractions are ignored. This relaxation of constraints is necessary due to the inordinate number of unknowns in the equation. Step two then calibrates the model further using row and column factoring. This consists, simply, of adjusting first rows, then columns by a constant to achieve the desired totals.

The calibration process is carried out below for the data in Table IV. The first step is to determine the zone

Table V - Gravity Model Intervals

DISTANCE INTERVAL (miles)	ZONE PAIRS IN INTERVAL	OBSERVED TRIPS
0 - 700	11,12,14,21,22,33,44,55,65,66	514
700 - 1000	23,24,32,34,41,42,43,56	712
1000 - 1600	13,31,35,36,46,64	768
1600 +	15,16,25,26,45,51,52,53,54,61,62,63	454

pairs that fall into the chosen intervals. Each interval will have an associated friction factor when the model is completed. Table V displays the chosen intervals with their respective zone pairs. Calibration begins with all F_{ij}'s equal to 1 (K_{ij}'s are not considered at this point).

Origination Calibration

Table VI - First Iteration Results

FROM ZONE	TO ZONE 1	2	3	4	5	6	Oi
1	1.792	9.199	6.385	8.194	15.85	8.579	50
2	10.96	56.29	48.22	57.04	97.02	52.49	322
3	40.33	255.6	169.2	227.6	399.9	216.4	1309
4	14.84	76.19	57.37	59.66	115.4	64.53	388
5	8.947	45.93	34.59	40.92	99.41	61.2	291
6	2.763	14.19	10.68	13.05	30.7	16.62	88
Dj	79.64	457.4	326.4	406.5	758.3	419.8	2448

Using the basic equation and initial friction factors yields the values in Table VI. Friction factors are adjusted according to the following (Stopher and Meyburg, 1975, p. 146):

$$F_{x+1} = F_x \frac{O_i}{O_x}$$

where: O_i = Actual originations
O_x = Originations calculated in iteration x
F_x = Friction factor at iteration x

Destination trips, or attractions, are disregarded at this point. After five iterations, improvements of the friction factors produce minimal differences between observed and calibrated originations, and the model is

Table VII - Fifth Iteration Results.

FROM ZONE	TO ZONE 1	2	3	4	5	6	Oi
1	1.891	9.71	6.153	8.649	15.31	8.286	50
2	12.3	63.16	42.62	50.42	99.6	53.9	322
3	41.94	229.3	192.7	204.2	415.8	225.1	1309
4	13.3	68.27	51.41	67.86	120.1	67.01	388
5	8.925	45.82	34.5	40.82	108.4	52.56	291
6	2.633	13.52	10.18	12.41	31.97	17.3	88
Calculated: Dj	80.99	429.8	337.5	384.4	791.2	424.1	
Observed: Dj	82	421	317	375	813	440	

prepared for row and column adjustments. The model at this stage is shown in table VII and the evolution of the friction factors is summarized in table VIII.

Row and Column Factoring

The model as displayed in the fifth iteration must now be adjusted to reflect appropriate D_j totals. This is accomplished by simply multiplying first columns and then rows by factors aimed at balancing projected totals with

Table VIII - Synopsis of Calibration.

Friction Factors (Fk_n)
CALCULATED VALUES (Tk_n)

Fk0	Tk1	Fk1	Tk2	Tk3	Fk3	Tk4	Fk4	Tk5	Fk5	Tk6
1.0	496	1.036	461.9	509.5	1.163	513.1	1.165	513.7	1.166	513.9
1.0	604	1.179	798.0	715.9	1.046	712.6	1.045	712.2	1.045	712.1
1.0	804	0.955	740.6	772.3	0.985	770.2	0.982	768.9	0.981	768.4
1.0	491	0.925	447.3	450.3	0.946	452.1	0.95	453.2	0.952	453.6

Table IX - Final Matrix After Row and Column Factoring.

From:		To: 1	2	3	4	5	6	Σ Oi
	1	2	10	6	8	16	9	50
	2	12	62	40	49	102	56	322
	3	42	225	181	199	428	234	1309
	4	13	67	48	66	124	70	388
	5	9	45	32	40	111	54	291
	6	3	13	10	12	33	18	88
Σ	Dj	82	421	317	375	813	440	2448

actual totals. The calibrated model is shown in table IX. For example the number of trips projected from zone 4 to zone 2 is 67.

Zone-to-Zone Factors

The model in table IX still reflects some differences in projected zone totals (e.g., 45 trips are projected between zone 5 and zone 2, while the actual data reflect only 28). For this reason the basic equation contains zone-to-zone adjustment factors (K_{ij}). The final step in creating the model is to compare projected and actual trip matrices and develop the K values by a simple ratio analysis.

The K Factors, shown in table X, along with the interval friction factors complete the derivation of the

Table X - Zone-to-Zone (K) Factors.

From: \ To:	1	2	3	4	5	6
1	1.916	0.595	5.782	0.844	0.926	1.72
2	1.558	2.293	0.564	0.572	0.906	3.292
3	0.773	0.814	1.132	1.424	1.247	0.697
4	0.842	1.014	1.51	0.789	0.777	2.244
5	9.005	1.598	0.718	0.763	0.793	2.173
6	2.655	1.648	1.19	4.019	0.798	0.662

model. The model can now be used, for this particular system, to distribute horizon-year forecasts from the generation sub-model.

Discussion

The final friction factors determined by the model are representative of the fact that most shipment lengths in the data set are very long. Average shipment length is 1170.2 miles for all 2448 shipments used for the gravity model. The significance of such a long average shipment length could be attributable to (a) supply and demand ("that's just the way it worked out") or (b) a level of equilibrium mileage for which MTMC is willing to pay. Had a continuously declining friction factor been employed, the results would not have reflected this fact.

Error

Just as with the generation sub-model, the sources of

error must be recognized here. Aggregation, the friction facto. and "carry over" error from the preceding sub-model are all clear sources of error in the model. In addition, the amount of "closure" required of the model during calibration can play a large part in reducing or creating error (Stopher and Meyburg, 1975, p. 155). Statistical methods, such as determining an acceptable level for Type-I or Type-II error, may prove helpful in this respect; however, the level of aggregation in the model will play a key role. For instance, a highly aggregated model is far less likely to achieve precise results. The amount of closure may also be a function of the desired outcome or use of the model. For predictive purposes (as proposed here) error left unaddressed during calibration will certainly impair predictive results.

Chapter 4

THE ASSIGNMENT SUB-MODEL: THE CARRIER'S PERSPECTIVE

While traffic assignment or "route choice", a standard for the urban traffic engineer analyzing congestion, is of little concern to MTMC in its day-to-day operations, it is imperative to understand the workings of the private carrier and possible effects on all phases of the modelling process.

The Commercial Carrier

The operations of commercial trucking company are surprisingly simple; customers call in with loads to be shipped from an origin city to a destination city, and the carrier must provide the right truck at the right place at the right time. If the carrier cannot provide an empty truck in the origin city within a short time - usually a day - it risks losing the load. Once the truck picks up the load, it heads directly to the destination city without intermediate stops where it once again becomes available. There are no fixed schedules or base terminals and all movement is in response to customer demand.

The traditional goal of routing commercial trucks has been to minimize "deadhead" miles i.e. empty miles from a driver's location to the next pickup point. Thus, in considering where to send a truck, the dispatcher must consider not only the revenue of a single load, but how well the truck will then be positioned to pick up subsequent

loads. Later, this chapter contains simple examples of how linear programming can be used to simulate the decisions of a commercial carrier seeking to minimize deadhead miles.

In these examples all movements for a given day are known. In reality, however, carriers will only know a fraction of the information required to make decisions, plan routes, and schedule trucks.

The uncertainty involved makes this task very difficult. At the start of the day the carrier may know only 30 - 40 percent of that day's loads and only 10 percent of the next day's. When a driver calls in, the dispatcher must either assign the truck to a known load, send it empty to a "deficit" region (one with typically more loads than trucks) or hold it in that region in anticipation of another load.

The high pressure environment, short lead times and demand uncertainty generally mean the dispatcher has little time to calculate the overall effect of a given move. This "fire-fighting approach" is a poor one because it causes excessive deadhead miles as well as loss of revenue from passing up profitable loads due to badly positioned trucks.

Consider the following example. A truck is dispatched from Dallas on Monday loaded enroute to Pittsburgh where it will arrive on Wednesday. The dispatcher will have (at least) several dozen options for the truck once it arrives (e.g., holding it in Pittsburgh, sending it loaded to New

York, empty to Chicago, etc.) This represents the "first move" available to the dispatcher. If the region has an average of 30 dispatch options, after three moves there are $30^3 = 27,000$ possible trajectories. How can one estimate the contribution of the original move given all its possible outcomes? Also, how can the dispatcher rank the various options according to expected profitability?

Another important issue is calculating the marginal contribution of an additional truck in a region. As the number of trucks in a region increases, one would expect the marginal value of each truck to decrease. How much more valuable is the 11th truck in New York on Friday compared with the 15th?

One such solution was developed by the Commercial Transport Division of North American Van Lines (NACT) in 1985. NACT assembled a team of Operations Research analysts to develop a computer model to enhance efficiency and eliminate the fire-fighting approach. The model, called LOADMAP (Load Matching and Pricing) replaced the standard goal of reducing deadhead miles with the loftier goal of maximizing profit (Powell and Sheffi, et al, 1988).

LOADMAP's database includes: expected number of loads between each pair of regions over the planning horizon, expected profit contribution of each load, expected cost and transit time of each load, current location of trucks, known (booked) loads, and profit contribution of future loads

(Powell and Sheffi, et al, 1988, p. 26.).

Two Views of Route Choice

Two views of route choice are popular: discrete choice and utility theory. Each is discussed below.

Discrete Choice

A carrier attempting to minimize costs on the network is faced with many choices with respect to routes. The discussion above pertaining to "trajectories" makes these decisions extremely difficult and somewhat risky. Even when all commitments are known, there are decisions to make that affect profits.

The following linear programming model looks at the choices made by carriers attempting to cover freight transport demand, while minimizing deadhead miles. The assumption being that minimum deadhead miles coupled with paid deliveries will maximize profits.

The base model is comprised of seven nodes labelled 1 to 7. In the model time is not a factor. It will be assumed that all deliveries can be made in one day. The distance in miles between the nodes is shown in the following matrix:

	1	2	3	4	5	6	7
	0	7	3	9	10	11	4
2	7	0	4	8	11	4	5
3	3	4	0	6	8	7	2
4	9	8	6	0	5	4	5
5	10	11	8	5	0	9	6
6	11	4	7	4	9	0	8
7	4	5	2	5	6	8	0

On any given day the dispatcher or truck manager has a known number of deliveries that must occur. For this example, required routes (for which the company will be paid by the ton-mile) are:

a. From 1 to 4 and 1 to 6
b. From 2 to 5 and 2 to 7

Each load is a truckload in and of itself. This represents the incompatibility problems faced by ammunition carriers for the government. Therefore no chaining of trips is possible. The task then is to designate a route for the truck that will meet freight demand and minimize freight demand.

By designating required routes from node i to node j as S_{ij} and deadhead routes as X_{ij} we can *see that each required* route must be entered and exited by a deadhead route until all required routes are exhausted (See Fig 6). By minimizing these "connecting" deadhead routes the carrier will minimize costs associated with these moves. The following linear programming formulation represents this relationship.

$$MIN\ \ Z = \sum_{ij}^{n} X_{ij} D_{ij}$$

$$s.t.: \quad \sum_{i}^{n} X_{ij} - \sum_{i}^{n} S_{ji} \leq 0$$

$$\sum_{i}^{n} X_{ji} - \sum_{i}^{n} S_{ij} = 0$$

Where:
X_{ij} = Deadhead routes from i to j
S_{ij} = Required routes from i to j
D_{ij} = Mileage from i to j

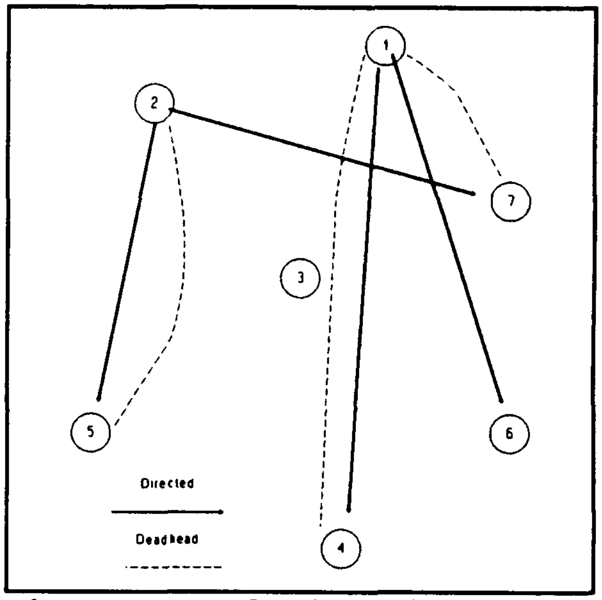

Figure 6 - Relationship Between Deadhead and Required Routes.

In this example distance is the only cost associated with each deadhead movement and the discrete choices of deadhead routing are made based upon distance. Appendix C contains General Algebraic Modelling (GAMS) linear programming computer runs of the model.

Utility Theory

As discussed previously the choices faced many times daily by the average carrier are not simply a function of mileage or any other fixed indicator. Many factors go into the freight managers decision to choose to carry a load, take a route, or send a particular type of truck.

Each factor influences the associated utility for each possible choice for any decision. Consider the following example. A fleet manager must send a truck loaded from i to j. The load he must carry dictates that he can send one of two types of truck-trailer configurations (a and b). Configuration "a" gets better mileage, but configuration "b" has a higher likelihood of acquiring a new load at

destination. Configuration "a" travels faster over flat routes, while "b" is as fast as a over hilly terrain.

The associated utility for different routes from i to j now becomes a complex decision that is represented by:

$$R \cdot U_x = \alpha + \beta \cdot Fuel + \gamma \cdot TravelTime + \delta \cdot Prob.ofReassignment + \eta \cdot M + \epsilon_x$$

Where: R = A dummy variable that indicates route acceptability of the load in question. (1 if route is acceptable 2 otherwise.
M = A dummy variable that indicates truck-trailer configuration.
Fuel = Fuel Cost
Time = Travel Time
Prob(Reassignment) = Chance of reassignment within some acceptable timeframe.

The fleet manager will choose route x based on its utility as compared to other routes. The probability of choosing route x over route y is given by:

$$P(x) = \frac{e^{U_x}}{e^{U_x} + e^{U_y}}$$

Such a representation of carrier activity could also prove useful in the distribution sub-model as a way of reducing the error in the friction and zone-to-zone adjustment factors.

Chapter 5

APPLICATIONS TO U.S. ARMY AMMUNITION SHIPMENTS

After a broad examination of freight models and two specific practical applications, this chapter discusses the techniques presented as they apply to the U.S. Army. Specifically, "What freight modelling tools/concepts can be used by MTMC to aid in the planning and analysis of ammunition shipments in CONUS?" All references to DOD ammunition shipments are taken from the database introduced in Chapter 3 and Appendix D. Each model type from Chapter 1 is discussed briefly, and an example of possible use is introduced.

Analysis Techniques Considered

In the previous chapters three basic types of models have been discussed. Each provides insight into the freight industry as it applies to the Army.

Equilibrium Models

In the case of U.S. Army Ammunition movements the relationship between the shipper (Military Traffic Management Command) and carrier (a limited number of specialized carriers), as well as the relationship between shipper and consumer (in both cases the U.S. Army), does not seem particularly well-suited for econometric equilibrium analysis. The value of a bullet to be fired on a range at Fort Jackson, South Carolina is the same (measured not in

dollars, but in training effect) regardless of its origin or associated transportation cost. Training of soldiers in preparation for national defense requires that certain schedules be met. If this means that ammunition must be transported from California to South Carolina, it will happen. Such a circumstance would require MTMC to pay a much higher price than would be expected. In a normal economy such a movement would not take place without a commensurate price increase at market.

Likewise, network equilibrium models adapted to Army munitions flows would be rendered useless by the same scenario; however, Harker's GSPEM assumptions , for the most part, hold true and are worthy of mention and lend some insight into the nature of the freight business.

Carriers Individually Minimize the Cost of Transporting Goods Over their Networks

Unlike the shipper they work for, specialized munitions carriers are profit-seeking organizations who must compete for revenues. The MTMC generally contracts the "lowest bidder" for each shipment. The bidder must then minimize costs over the network to turn a profit. The forces at work in this process and their modelling effects are discussed in Chapter 4.

Carriers Price According to Demand

As in any economy, the demand for a good or service will lead to an equilibrium price. This price, at equilibrium, will reflect the supply of the good or service

as well. Harker produced a "rate function" to describe the way carriers fix the prices of services under different scenarios. Such a rate function, developed below, shows that ton-mileage is the greatest indicator of the rate at that the government will be charged for services.

Shippers Individually Minimize the Cost of Shipping Goods Over Their Network

Through a competitive bidding process, MTMC seeks to minimize the rate paid for each shipment, while still achieving a desired LOS.

Similar to Harker's rate function derivation, the U.S. Army munitions transport database was analyzed using simple linear least squares regression to determine the most prevalent factor in determining the rate charged by carriers. Shown below is the "best" fit obtained using LOTUS 1-2-3 spreadsheet-based regression.

The objective of the regression was to determine predictors for the total paid charges from the database. total weight was combined with Rand McNally mileage to produce an industry-standard rate term "Ton-Miles." Dummy or indicator variables (MTHD_D=1 for dromedary and MTHD_V=1 for van) were used to represent MTHD TRANS entries from the database. The term "dromedary" is used for a smaller container that provides more segregation and security commonly used for small ammunition shipments. If both dummy variables equal one, this indicates a flatbed shipment. The modified database for the final regressions is represented

by the following:

MTHD_D	MTHD_V	TON-MILES	CHARGES
1	0	700.35	1161.94
0	1	64378.15	5662.86
0	1	32999.25	3963.16
0	0	43414.8	6903.20
1	0	1173	892.09

A step-wise regression method was used to determine the best models. The best models are:

Regression #1:

Constant	937.6708	
Std Err of Y Est	1308.060	
R Squared	0.709104	
No. of Observations	1543	
Degrees of Freedom	1541	
		ton-miles
X Coefficient(s)		0.081765
Std Err of Coef.		0.001334
ttest		61.28980

Regression #2:

Constant		1465.735	
Std Err of Y Est		1297.033	
R Squared		0.714359	
No. of Observations		1543	
Degrees of Freedom		1539	
	d	**v**	**ton-miles**
X Coefficient(s)	-479.646	-630.514	0.079446
Std Err of Coef.	130.4456	121.8052	0.001501
ttest	-3.67698	-5.17641	52.90036

The first result reflects an approximate $.08/ton-mile rate regardless of whether the shipment is a van, dromedary, or flatbed shipment. The second result yields three fitted regression equations depending upon the type of shipment.

```
VAN CHARGES  = 1465.735  -  630.514  +  .079*TON-MILES
             = 835.221  +  .079*TON-MILES
DROM CHARGES = 1465.735  -  479.646  +  .079*TON-MILES
             = 986.089  +  .079*TON-MILES
FLATBED CHARGES = 1465.735 + .079*TON-MILES
```

These results give a more realistic indication of industry charging practices than simply regressing charges upon ton-mileage. Of the 1544 database entries used for this analysis, 636 were dromedary, 755 were van and 152 were flatbed shipments. These regression results indicate a statistically significant difference in the price of the three modes. It should be noted that additional charges for protective services were analyzed and did not show statistical significance; however, it is known that these charges exist, comprising the error term in the regression. It is worth noting, however, that coding in the database for protective services is nonstandard. This may account for the failure to obtain significance. It is also possible that the flatbed rate is artificially inflated due to the fact that most flatbed shipments are much larger in size than other shipments.

In any case, it is evident that the driving force behind the pricing of government munitions transport is mileage. The MTMC will minimize its costs by minimizing ton-mileage over the network.

Summary

Equilibrium models generally suited for aggregate analysis give planners an important tool to observe "broad-brush" effects of transport and economic policy. Such models are not well-suited as planning tools for DOD munitions shipments; however, they aid in a conceptual

analysis of the forces at work. The causal relationships shown in figure 7 represent the decision variable MTMC managers utilize daily. They are the same variables modelers must seek to capture to be effective.

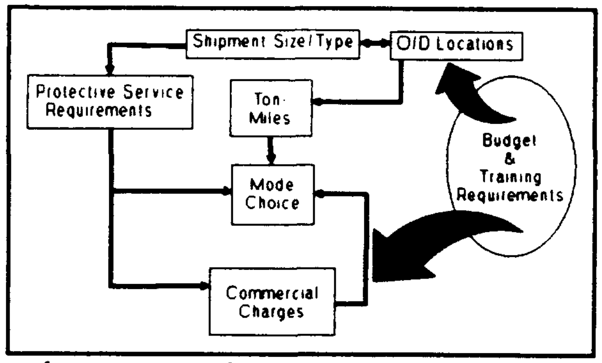

Figure 7 - Causal Relationships.

Mode Choice Models

Mode choices for the military with respect to the transport of munitions are:

a) Military Truck

b) Commercial Truck

c) Rail

Military trucks are not permitted to compete with the civilian trucking industry within CONUS during peacetime and are limited to moving only sufficient quantities to provide for "training of personnel." Such training exercises are carefully scrutinized by the transport industry to ensure agreed upon movement ceilings are adhered to.

The Military Traffic Management Command Transportation Engineering Agency Reference 92-700-2, "Logistics Handbook For Strategic Mobility Planning", outlines mode choice guidelines between rail and highway for resupply cargoes in the event of overseas deployment. The selection guide is based on mileage and cargo weight for ammunition. All

ammunition shipments travelling less than 400 miles are to be designated highway shipments. Between 400 and 800 miles shipments less than 24 tons are highway shipments, with larger shipments moving by rail. Above 800 shipment miles the weight cut-off lowers to 12 tons.

These criteria are guidelines for resupply during wartime. A quick look at the database shows that they are not followed during normal peacetime movements where virtually all movements are made by commercial truck (except for those allowed for military trucks). In recent history the military has embraced the commercial trucking industry. The more reliable and flexible trucking industry was the preferred choice over rail during the Gulf War.

Already the DOD is the "single largest customer of transportation services in the U.S." (Misch 1993, p.12) with over $3.6 Billion per year to the trucking industry alone. Over 70 percent of all munitions for the Gulf War, to include missiles, were moved by commercial truck to ports of embarkation. The trucking industry is so reliable that there is no need to create a standby pool of trucks to meet the needs of war (Misch 1993, p.13).

Are Mode Choice Models worth discussion then in light of this fact? The answer is yes. Given that all of the shipments discussed here are made by private truck, there are still choices available to MTMC. Namely the shipment may be moved by flatbed truck, containerized or by

dromedary. These choices resemble the type of disaggregate decisions made by a manager choosing between conventional modes.

Having previously determined that all of the shipments in question were made by truck, the question is whether or not mode choice models can lend insight into the wide "sub-mode" variability (Of the 1544 data entries used to look at mode choice 636 were by dromedary, 756 by van, and 152 by flatbed).

It is possible that there are purely operational reasons that account for these numbers (ie. extremely large or outsized shipments generally are flatbed movements, while very small, pilferable shipments are dromedary movements). However, in the previous section it is shown that there is a statistically significant difference between the price of the three sub-modes. The disaggregate decision-making process described by Winston may be similar in this case.

The greatest difference in the case of military munitions movement is the role that transit time plays in the decision-making process. In all of the models discussed, speed of delivery was extremely important to the shippers who sought to maximize profits and minimize inventories. A difference in transit time between sub-modes is non-existent. In peacetime, transit time is of little importance to the military as long as forecasted required delivery dates are met; however, in wartime transit time

becomes very important.

Summary

The data used for this paper do not lend themselves to mode choice analysis as discussed here. It is probably possible to project local "sub-mode" usage rates based upon cost and expected utility matched with forecasted shipments. This information might be of little use to the military, but could prove useful to carriers in their planning for future loads.

It is not hard to imagine the criteria discussed by Winston (1990) as the major factors responsible for high truck-usage rates during Operation Desert Shield/Storm. Few customers could be more dependent upon speed, reliability and flexibility than the DOD during a war.

As base closures increase and a smaller Army with more focused mission and training requirements emerges, mode choice could become important once again. Recall the causal relationship developed in the previous section. By consolidating loads from fewer origins to a restricted number of destinations, MTMC might find rail more advantageous in peacetime (lower ton-mile charges for large loads with albeit less flexibility).

Macro Models

The most likely uses for the military with UTPS style macro models lie in the examples presented in the previous chapters -- trip generation and distribution.

Trip Generation

While it does not seem like it should be, the DOD's ammunition consumption is extremely difficult to forecast. This is due to the fact that actual conflicts (wars) tend to draw down reserves that were meant for training purposes. When this happens the training is not cancelled. Usually ammunition is brought from elsewhere and managers go about the task of bringing reserve levels back to where they should be. This is a continual process that is well documented with data such as that used in this paper.

By combining the simple methods displayed here and others used elsewhere (stochastic methods, trend analysis, etc.) MTMC could create a valuable forecasting tool.

Distribution

If trip generation/attraction information is useful as an analysis tool, then the gravity model should enhance that information. Projections from such a model could be compared to projections made by ammunition managers to provide an even further level of calibration and higher level of accuracy.

Application of Concepts

Example: "Guaranteed Traffic"

The MTMC is attempting to replace the continual process of carrier bidding for every single shipment solicited. The proposed replacement is known as "guaranteed traffic" (GT) and operates on a zonal basis. Under this concept MTMC

would enter into a contract with a <u>single</u> carrier in a zone, wherein the carrier would be guaranteed (and legally bound to move) all traffic in that zone. There is no actual guarantee of any level of traffic, simply "all" of it would be dedicated to the carrier. The MTMC's hope is that reducing the carrier's uncertainty (as discussed in Chapter 4) will lead to lower prices.

<u>Using Gravity/Distribution Models</u>

The problem with MTMC's proposal is that there is no guarantee of traffic. For such a plan to be profitable for the carrier, a certain level of traffic must be maintained. For while it may be true that a GT carrier could cut costs by using a fixed number of trucks in the zone, any possible savings could be lost during a "drought" where those trucks sat idle. Needless to say carriers have not been jumping at the opportunity to establish GT agreements, citing the risk due to uncertainty as their main problem with the program. The MTMC cannot discount this claim based on fluctuations in ammunition flow.

It is here that a carefully computed and calibrated generation/distribution model could assist in locating likely zones for such agreements and perhaps "sell" carriers on the actual level of risk in each zone. While it would probably not be wise to "guarantee" levels based on model results, there is certainly potential for use.

Summary

The latest fad in corporate America is "reengineering." Simply put, the concept requires that managers look at their operations in a new light, discarding "the way we have always done it." Looking for ways to do more for less have meant new life for many U.S. companies. The DOD is now forced to embrace some of the same concepts. New planning tools can help to do their part in saving MTMC money. The methods discussed in this paper are possible methods for future planners to view the freight business that has become so vital for the DOD.

A strong grasp of the causal relationships at work will enable MTMC to prepare better forecasts in peacetime and in wartime. These forecasts, in turn, should bring MTMC better credibility at the bargaining table when negotiating rates.

The recipe for MTMC is to (a) focus on causal relationships, specifically those that can lead to higher savings and improved efficiency; (b) produce forecasting models based upon those relationships, constantly fine-tuning them to compliment existing forecasts, and (c) continue to explore other methods to keep pace with the industry, such as simulation. All of these spell possibilities for better service and relations with carriers.

Appendix A

U.S. Army Safety and Security Requirements

Military ammunition/munitions shipments are placed into security risk categories based on their potential danger to the population as a result of theft, loss, or accidental detonation/release. The categories, from I to IV, are summarized below:

CATEGORY I: Includes nonnuclear missiles and rockets in a ready to fire configuration.

CATEGORY II: Light automatic weapons and explosives.

CATEGORY III: Includes components for Category I and II items as well as incendiary grenades, fuses for high explosives and bulk explosives.

CATEGORY IV: Includes shoulder fired weapons (not automatic) and ammunition with nonexplosive projectiles.

These security categories are based upon hazard classes that correspond to the new Code of Federal Regulations 49 (CFR 49) categories for hazardous materials discussed in Appendix B.

Government Protective Service Requirements

To safeguard dangerous cargo the government requires carriers to perform Transportation Protective Services (TPS). These requirements vary based on the security category of the cargo.

Dual Driver Protective Service (DD) requires continuous

attendance and surveillance of a shipment by qualified dual drivers. Carriers providing DD must:

a. Ensure during brief stops enroute. At least one of the drivers remains in the cab of the vehicle or within 25 feet provided the vehicle is within full, unobstructed view.

b. Ensure during lengthy stops that the vehicle is parked at a carrier terminal or state approved safe haven under Code of Federal Regulations 49.

c. Dual drivers may or may not be required to possess National Agency Check credentials (NAC).

Security Escort Vehicle Service (SEVS) calls for two unarmed drivers in an escort trail vehicle to maintain constant surveillance over the freight vehicle. The purpose is to enable rapid response to emergency situations.

Constant Surveillance Service (CSS) requires constant, 24-hour surveillance of the freight vehicle by a driver or terminal representative.

The Defense Transportation Tracking System (DTTS) requires commercial carriers to install satellite transponders in their commercial vehicles. Commercial carriers are required to purchase satellite transponders and associated equipment. They then charge the DOD a service fee to permit DOD to receive tracking information and communications data that is transmitted to a central DOD location. The DTTS also receives origin and destination

information and integrates it with the tracking and communications data.

Effects on Carrier and Shipper Behavior

The government is rightfully very selective with regards to which carriers are permitted to carry munitions. The protective measures required of carriers promote safety and ensure accountability.

The requirements placed on carriers eliminate most carriers from the munitions transport market. In fact, fewer than ten carriers will be active at any given time, nationwide (Discussion with MTMC Director of Inland Traffic, May 1993). Carrier performance is followed closely, and violations of the guidelines set forth by MTMC can mean disqualification.

Appendix B

HAZMAT Transport Regulations.

New HAZMAT Legislation

Three new pieces of legislation in the past three years will have a dramatic impact on the HAZMAT transport industry. They are:

a. The Hazardous Materials Transportation Uniform Safety Amendments Act of 1990 (HMTUSA).

b. Docket HM 181, 1991.

c. Docket HM 126F, 1992.

HMTUSA

The HMTUSA amendments to the Hazardous Materials Transportation Act (HMTA) contain provisions for federal preemption for routing, disclosure, licensing, shipper safety ratings, and emergency response.

In 1990, the House Committee on Energy and Commerce, along with the House Committee on Public Works and Transportation, jointly disclosed the following findings that needed attention (HMTUSA 1990, p.2):

a. Many state laws vary from federal laws as well as surrounding states. This problem is confounding shippers and creating unnecessary hazards and conflicts.

b. There exists a need for an adequately trained emergency response force.

c. Safe, efficient movement of HAZMAT is vital to

the nation's commerce.

Key features of HMTUSA affecting highway operations pertain to highway routing and emergency response.

Routing

The HMTUSA designates the following criteria for selection of HAZMAT routes:

a. Each route will enhance overall public safety.

b. Each jurisdiction shall have the opportunity to comment prior to enacting.

c. The selection of routes may not unreasonably burden the shipper.

d. The Secretary of Transportation will resolve disputes and approve routes.

In an attempt to normalize routes lawmakers also called on the secretary to update and publish a list of currently effective HAZMAT routes.

An important feature of this new legislation precludes states and local governments from passing laws on routing or time of day restrictions until they meet federal standards for their decisions (HMTUSA 1990, p. 4). Such state and local requirements have the effect of exporting risk to other areas and burdening the transportation industry with costly circuitous routes.

Emergency Response

The HMTUSA expressed the need for a state by state inventory of emergency responders and their capabilities and

contains provisions for training emergency responders with funds provided by fees imposed on shippers. Specifically, these funds are designated to pay for (Dungan 1991, p. 1-5):

a. Standardized training for HAZMAT responders.

b. Gathering data to improve quantification of risks.

c. Upgrade of emergency planning doctrine.

d. Allocation of regional HAZMAT teams.

HMTUSA imposes most of the burden on shippers for providing emergency response information. Carriers of all HAZMAT shipments are required to provide an emergency 24-hour telephone number at which information on mitigation of HAZMAT spills can be obtained (Donohue 1991, p. 1-15).

HM-181

Docket HM-181 modifies the regulatory scheme governing packaging and placarding requirements. The new rules are "primarily designed to force American transport regulation into the scheme adopted for international transportation" (Shelton 1992, p.13). The changes give shippers more flexibility than they have had in the past, but increase shipper responsibility.

Packaging

Under the new rules shippers can chose any packaging performance criteria they wish and will be responsible for testing packages themselves. The possibility of increased litigation resulting from claims is likely to increase due

to this aspect of the regulation.

Placarding

HM-181 brings changes to longstanding hazard communications procedures. Mandatory use of UN numerical designations will replace written messages by October 1993. Numerical designations are designed to be more precise, providing emergency responders with more detailed information regarding shipment contents. Typical changes will be:

- "8" instead of "Flammable Liquid"
- "1.1" instead of "Explosives A"

HM-126F

This docket prescribes training requirements for "HAZMAT Employees" as mandated by HMTUSA. A HAZMAT Employee is any person who performs the following functions in conjunction with HAZMAT (Shelton 1992, p.14):

a. Load, unload, handle.

b. Test, recondition, repair.

c. Prepare for shipment.

d. Responsible for safety.

e. Vehicle operator.

Training requirements include awareness, function specific, emergency response and accident avoidance.

Appendix C

GAMS Linear Program Runs

Utilizing a node balancing scheme for both the incoming and outgoing deadhead routes for each required route gives the following formulation in GAMS Format:

```
* MINIMIZE DEADHEAD ROUTES GIVEN REQUIRED DELIVERIES
    SETS
         N   nodes    / D1, D2, C1, C2, C3, C4, C5 /
         ALIAS (N,I,J,) ;
    TABLE D(I,J)  distance in miles between nodes
                   D1    D2    C1    C2    C3    C4    C5
             D1     0     7     3     9    10    11     4
             D2     7     0     4     8    11     4     5
             C1     3     4     0     6     8     7     2
             C2     9     8     6     0     5     4     5
             C3    10    11     8     5     0     9     6
             C4    11     4     7     4     9     0     8
             C5     4     5     2     5     6     8     0     ;

    TABLE S(I,J)  required routes
                  D1     D2     C1     C2     C3     C4     C5
             D1   0      0      0      1      0      1      0
             D2   0      0      0      0      1      0      1
             C1   0      0      0      0      0      0      0
             C2   0      0      0      0      0      0      0
             C3   0      0      0      0      0      0      0
             C4   0      0      0      0      0      0      0
             C5   0      0      0      0      0      0      0    ;
    PARAMETER  BEG(I)  beginning node specification ;
           BEG("C1") = 1 ;
    PARAMETER END(I)  ending node specification ;
           END("C2") = 0 ;
    VARIABLES
           X(I,J)  deadhead movements  from i to j
           Z       total deadhead miles ;
    POSITIVE VARIABLE X ;
    EQUATIONS
       DHMILES     define objective function
       NB   deadhead routes terminate at a required route
       NBB  deadhead routes begin at the end of a required
          route ;
    DHMILES .. Z  =E=  SUM((I,J), X(I,J)*D(I,J)) ;

    NB(J) ..
```

```
SUM(I,X(I,J)) - SUM(I,S(J,I)) - END(J) =G= 0 ;
NBB(J) ..
SUM(I,X(J,I)) - SUM(I,S(I,J)) - BEG(J) =E= 0 ;
MODEL KTRANS /ALL/ ;
SOLVE KTRANS USING LP MINIMIZING Z ;
DISPLAY X.L, Z.L;
```

In this formulation no ending location has been designated; however, a start location of C1 has been entered. The values of X meeting the node balancing constraints multiplied by the distance yield the total deadhead miles. This is the objective function that must be minimized.

Running the program yields the following output:

```
G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S
T E M                                          08/02/93 15:05:38
PAGE     10
 E X E C U T I N G
                                                GAMS 2.05 IBM CMS
67 VARIABLE  X.L MOVEMENT FROM I TO J (LOADED OR UNLOADED)

              D1          D2          C3

 C1        1.000

 C2                    1.000

 C3                                1.000

 C4                    1.000

 C5        1.000


 ----      67 VARIABLE  Z.L              =        19.000 TOTAL
DEADHEAD MILES
```

The C3..C3 designation indicates no movement away from

C3 at the end of the required routes. The objective value has been minimized at 19 miles. Designating a final node of C2 (presumably to preposition for the next day's movements) yields:

```
G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S
T E M                                        08/02/93 20:11:39
PAGE      10
 E X E C U T I N G
                                              GAMS 2.05 IBM CMS
 67 VARIABLE  X.L MOVEMENT FROM I TO J (LOADED OR UNLOADED)
               D1          D2          C2
  C1         1.000
 C2                                1.000
 C3                      1.000
 C4                      1.000
 C5        1.000
  ----      67 VARIABLE  Z.L       .     =        22.000 TOTAL
DEADHEAD MILES
```

Again there is "no movement" indicated, the required routes were rearranged to make C2 the final node. This maneuver did not come without cost as deadhead miles rose to 22.

This simple model begins to highlight the decisions a trucking company must make. Realistically, a company would have more trucks than one operating in even the most remote locations. For this reason the basic model was altered to

entertain the possibility of multiple trucks.

This was accomplished by adding another subscript. X(I,J,K) now designates a deadhead route made by the truck that started the day at node i, from node j, to node k. Multiple trucks are permitted to start at nodes. Similarly, the parameters D and S were expanded to be of the same dimension. These expansions were more for the sake GAMS than for necessity. D(I,J,K), for instance is little more than the same distance table repeated for each truck.

Once more the nodes are balanced going into and out of required routes. In addition, two more constraints were necessary:

a. Trucks that did not begin at a node in the network could not be used (TRK).

b. Every truck in the zone must be used for an initial movement from its start point -- even if that movement is a no movement (TRK2).

The second constraint prevents the use of a truck at a distant node without it physically moving there.

The GAMS formulation is as follows:

```
* MINIMIZE DEADHEAD ROUTES GIVEN REQUIRED DELIVERIES
* MULTIPLE TRUCKS
    SETS
        N   nodes    / N1 *  N7 /
        ALIAS (N,I,J,K) ;
PARAMETER D(I,J,K)  distance in miles between nodes /
N1*N7.N1.N2 7, N1*N7.N1.N3 3, N1*N7.N1.N4 9, N1*N7.N1.N5 10,
N1*N7.N1.N6 11, N1*N7.N1.N7 4, N1*N7.N2.N1 7, N1*N7.N2.N3 4,
N1*N7.N2.N4 8, N1*N7.N2.N5 11, N1*N7.N2.N6 4, N1*N7.N2.N7 5,
N1*N7.N3.N1 3, N1*N7.N3.N2 4, N1*N7.N3.N4 6, N1*N7.N3.N5 8,
```

```
N1*N7.N3.N6 7, N1*N7.N3.N7 2, N1*N7.N4.N1 9, N1*N7.N4.N2 8,
N1*N7.N4.N3 6, N1*N7.N4.N5 5, N1*N7.N4.N6 4, N1*N7.N4.N7 5,
N1*N7.N5.N1 10, N1*N7.N5.N2 11, N1*N7.N5.N3 8, N1*N7.N5.N45,
N1*N7.N5.N6 9, N1*N7.N5.N7 6, N1*N7.N6.N1 11, N1*N7.N6.N2 4,
N1*N7.N6.N3 7, N1*N7.N6.N4 4, N1*N7.N6.N5 9, N1*N7.N6.N7 8,
N1*N7.N7.N1 4, N1*N7.N7.N2 5, N1*N7.N7.N3 2, N1*N7.N7.N4 5,
N1*N7.N7.N5 6, N1*N7.N7.N6 8          /

PARAMETER S(I,J,K)  required routes                  /
   N1.N1.N4 1, N1.N1.N6 1, N2.N2.N5 1, N2.N2.N7 1  /

PARAMETER BEG(J)  beginning node specification       /
   N3  1   /

VARIABLES
   X(I,J,K)  movement from j to k by truck i
   Z       total deadhead miles ;

INTEGER VARIABLE X ;

EQUATIONS

   DHMILES     define objective function
   NB      deadhead routes terminate at a required route
   NBB     deadhead routes begin at the end of a required
           route
   TRK     only available trucks can be used
   TRK2    must move from initial location   ;

   DHMILES .. Z  =E=  SUM((I,J,K), X(I,J,K)*D(I,J,K)) ;
   NB(K) ..
   SUM((J,I), X(J,I,K)) - SUM((J,I), S(J,K,I)) =G= 0  ;
   NBB(K) ..
   SUM((J,I), X(J,K,I)) - SUM((J,I), S(J,I,K)) - BEG(K) =E=
           0 ;
   TRK(J)$(NOT BEG(J)) .. SUM((I,K), X(J,I,K)) =E= 0    ;
   TRK2(J)$(BEG(J)) .. SUM(K, X(J,J,K)) =G= 1 ;
   MODEL KTRANS /ALL/ ;

   SOLVE KTRANS USING MIP MINIMIZING Z ;

   DISPLAY X.L, Z.L;
```

In this formulation once again one truck is spotted at node 3 -- C1 in the base

model. (Note that node designators have been changed in this formulation for ease of

data entry). The output is as follows:

```
G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S
T E M                                          08/02/93 20:05:02
PAGE     21
 E X E C U T I N G
                                                GAMS 2.05 IBM CMS


 ----     64 VARIABLE  X.L   MOVEMENT FROM J TO K BY TRUCK I

                 N1          N2          N5

 N3.N3        1.000
 N3.N4                    1.000
 N3.N5                                1.000
 N3.N6                    1.000
 N3.N7        1.000


 ----     64 VARIABLE  Z.L     =        19.000 TOTAL DEADHEAD
MILES


 **** FILE SUMMARY FOR USER KRS126

 INPUT     TRUCK4   GAMS     E
 OUTPUT    TRUCK4   LISTING  E

 EXECUTION TIME       =        0.350 SECONDS
```

The same objective value and optimal solution are produced with this single truck as

with the base model.

By using the model to spot multiple trucks in the analysis zone, we can see the type of decision that would more realistically be made by a trucking company. By placing trucks at nodes N2, N3, N5 and N6 we get the following output:

```
----     64 VARIABLE  X.L    MOVEMENT FROM J TO K BY TRUCK I

                 N1          N2          N4          N5
  N6

 N2.N2                    1.000
 N2.N4                                1.000
 N2.N5                                            1.000
 N2.N6
```

```
1.000
 N2.N7        1.000
 N3.N3        1.000
 N5.N5                                            1.000
 N6.N6                      1.000


----     64 VARIABLE  Z.L    =        11.000 TOTAL DEADHEAD
MILES

 **** FILE SUMMARY FOR USER KRS126

 INPUT      TRUCK4    GAMS      E
 OUTPUT     TRUCK4    LISTING   E
```

The output indicates that only three of the four available trucks were utilized to minimize deadhead miles. However, the deadhead miles were reduced by adding multiple trucks. Although all of the outputs are not shown, a maximum number of three trucks placed at different nodes yielded the lowest number of deadhead miles while using all trucks. This type of analysis, coupled with good demand forecasting could make the difference for a firm trying to operate on a zonal basis, as the Army is beginning to demand of ammunition carriers.

Appendix D

U.S Army Ammunition Database

The following is an explanation of terms associated with the U.S. Army database of ammunition shipments used for portions of this paper (Table XI on page 76).

OSTATE - Origin state of shipment.

OCITY - Origin city.

DSTATE/DCITY - Destination state and city.

MILEAGE - Measured in miles from origin to destination.

OGBLOC - Code for origin.

UFCNMFC - Code for type of ammunition shipment.

1 = Class A

2 = Class B

MTHDTRANS - Code for type of shipment (trailer).

D = Dromedary

V = Container (van)

F = Flatbed

OCARR - USDOT abbreviation for commercial carrier.

TWEIGHT - Total weight of shipment.

PAIDCHARGES - Total payment for shipment.

YR/MO - Year and month of shipment.

DELDAYS - Number of days from receipt of contract to delivery.

<u>APR</u> - Degree of protective services required. Code is nonstandard throughout the United States.

<u>GBL</u> - Government Bill of Lading number on contract.

Table XI – SAMPLE OF U.S. ARMY AMMUNITION DATABASE

OSTATE	OCITY	DSTATE	DCITY	MILEAGE	OGBLOC	UFC NMPC	MTHDTRAN	OCARR	TWEIGHT	PAIDCHRGES	YR	MO	DELDAYS	APR	GBL
IN	CRANE	KY	CAMPBE	110	GONM	2	D	WITT	882	696.00	92	9	29	21	G1002547
IN	CRANE	KY	CAMPBE	110	GONM	1	V	TSMT	35550	879.00	92	10	18	21	G1002566
IN	CRANE	KY	CAMPBE	110	GONM	1	V	TSMT	27043	1039.00	92	10	1	21	G1002567
IN	CRANE	KY	CAMPBE	110	GONM	1	D	WITT	2209	876.00	92	9	29	21	G1003052
IN	CRANE	KY	CAMPBE	110	GONM	2	D	BYLE	3120	556.19	92	10	2	21	G1003093
IN	CRANE	KY	CAMPBE	110	GONM	2	D	BYLE	3120	556.19	92	10	2	21	G1003093
IN	CRANE	KY	CAMPBE	110	GONM	1	V	BAGT	41246	1159.00	92	12	1	21	G1003532
IN	CRANE	KY	CAMPBE	110	GONM	1	D	BYLE	776	696.00	92	12	1	21	G1003553
IN	CRANE	KY	CAMPBE	110	GONM	1	D	WITT	2406	990.00	92	12	1	21	G1003563
IN	CRANE	KY	CAMPBE	110	GONM	2	V	BAGT	18664	1039.00	92	12	1	21	G1003594

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